CLAIMS

What is claimed is:

1. A system for co-production of hydrogen and electrical energy comprising:

a fuel cell assembly comprising a plurality of fuel cells, the fuel cells further comprising a cathode inlet for receiving a compressed oxidant, an anode inlet for receiving a fuel feed stream, an anode outlet in fluid communication with an anode exhaust stream and a cathode outlet in fluid communication with a cathode exhaust stream; wherein at least a portion of the fuel feed stream reacts with the oxidant to produce electrical power and the anode exhaust stream comprises hydrogen; and

a separation unit in fluid communication with the fuel cell assembly, wherein the separation unit is configured to receive the anode exhaust stream from the fuel cell assembly to separate hydrogen from the anode exhaust stream.

2. The system according to claim 1, wherein the fuel cell assembly is operated in a low utilization mode, in which the fuel feed stream is consumed at a rate less than or equal to 70%.

3. The system according to claim 1, wherein the fuel cell assembly is operated in an enhanced hydrogen production mode.

4. The system according to claim 1, wherein the fuel cell assembly is operated at a voltage of about 0.7 volts to about 0.85 volts.

5. The system according to claim 1, wherein the mole fraction of hydrogen at the anode outlet is between about 0.1 to about 0.5

6. The system according to claim 1, wherein the oxidant is air.

7. The system according to claim 1, wherein the fuel feed stream comprises at least one fuel selected from the group consisting of natural gas, methane, and a coal derived gas.

8. The system according to claim 1 further comprising a heat exchanger configured to receive and heat the fuel feed stream using the anode exhaust stream from the fuel cell assembly.

9. The system according to claim 1, wherein the fuel cell is selected from the group consisting of solid oxide fuel cells, , molten carbonate fuel cells, , regenerative fuel cells, , and protonic ceramic fuel cells.

10. The system according to claim 9, wherein the fuel cell is a solid oxide fuel cell.

11. The system according to claim 1, wherein at least a portion of the anode exhaust stream is recycled back to the anode inlet after separation of hydrogen.

12. The system according to claim 1, wherein the anode exhaust stream further comprises carbon monoxide, carbon dioxide, unreacted fuel and water.

13. The system according to claim 12, wherein the separation unit comprises a carbon dioxide separator to separate carbon dioxide from the anode exhaust stream.

14. The system according to claim 13, wherein the carbon dioxide separator is selected from the group consisting of at least one chemical absorber, pressure swing adsorber, cryogenic separator, membrane separator and carbon dioxide liquefier.

15. The system according to claim 12, wherein the separation unit further comprises a low temperature shift reactor for converting carbon monoxide to carbon dioxide and a hydrogen separator.

16. The system according to claim 15, wherein the carbon dioxide is separated from the anode exhaust stream in at least one location selected from the group consisting of a location prior to the low temperature shift reactor, a location after the low temperature shift reactor and a combination thereof.

17. The system according to claim 15, wherein the hydrogen separator comprises at least one membrane.

18. The system according to claim 12, wherein the separation unit further comprises a moisture separator to separate water from the anode exhaust stream.

19. The system according to claim 18, wherein the moisture separator is selected from the group consisting of at least one condenser, molecular sieve bed and chiller.

20. A system for co-production of hydrogen and electrical energy comprising:

a fuel cell assembly comprising a plurality of fuel cells, the fuel cells further comprising a cathode inlet for receiving a compressed oxidant, an anode inlet for receiving a fuel feed stream, an anode outlet in fluid communication with an anode exhaust stream and a cathode outlet in fluid communication with a cathode exhaust stream; wherein at least a portion of the fuel feed stream reacts with the oxidant to produce electrical power and the anode exhaust stream comprises hydrogen; and

a separation unit in fluid communication with the fuel cell assembly, wherein the separation unit is configured to receive the anode exhaust stream from the fuel cell assembly to separate hydrogen from the anode exhaust stream;

wherein the fuel cell assembly is operated at a low utilization mode, in which the fuel feed stream is consumed at a rate less than or equal to 70%.

21. The system according to claim 20, wherein the oxidant is air.

22. The system according to claim 20, wherein the fuel cell assembly is operated at a voltage of about 0.7 volts to about 0.85 volts.

23. The system according to claim 20, wherein the mole fraction of hydrogen at the anode outlet is between about 0.1 to about 0.5.

24. The system according to claim 20, wherein the fuel cell is selected from the group consisting of solid oxide fuel cells, , molten carbonate fuel cells, , regenerative fuel cells, , and protonic ceramic fuel cells.

25. The system according to claim 24, wherein the fuel cell is a solid oxide fuel cell.

26. The system according to claim 20, further comprising a heat exchanger configured to receive and heat the fuel feed stream using the anode exhaust stream from the fuel cell assembly.

27. The system according to claim 20, wherein the anode exhaust stream further comprises carbon monoxide, carbon dioxide, unreacted fuel and water.

28. The system according to claim 27, wherein the separation unit comprises a carbon dioxide separator to separate carbon dioxide from the anode exhaust stream.

29. The system according to claim 28, wherein the separation unit further comprises a low temperature shift reactor for converting carbon monoxide to carbon dioxide and a hydrogen separator.

30. The system according to claim 27, wherein the separation unit further comprises a moisture separator to separate water from the anode exhaust stream.

31. A system for co-production of hydrogen and electrical energy comprising:

a fuel cell assembly comprising a plurality of fuel cells, the fuel cells further comprising a cathode inlet for receiving a compressed oxidant, an anode inlet for receiving a fuel feed stream, an anode outlet in fluid communication with an anode exhaust stream and a cathode outlet in fluid communication with a cathode exhaust stream; wherein at least a portion of the fuel feed stream reacts with the oxidant to produce electrical power and the anode exhaust stream comprises hydrogen; and

a separation unit in fluid communication with the fuel cell assembly, wherein the separation unit is configured to receive the anode exhaust stream from the fuel cell assembly to separate hydrogen from the anode exhaust stream;

wherein the fuel cell is operated at a low utilization mode in which the output voltage from the fuel cell assembly is maintained substantially below 1.0 volt.

32. The system according to claim 31, wherein the fuel cell is selected from the group consisting of solid oxide fuel cells, molten carbonate fuel cells, regenerative fuel cells, and protonic ceramic fuel cells.

33. The system according to claim 32, wherein the fuel cell is a solid oxide fuel cell.

34. The system according to claim 31, wherein the fuel cell assembly is operated at a voltage of about 0.5 volts to about 0.7 volts.

35. A system for co-production of hydrogen and electrical energy comprising:

a solid oxide fuel cell assembly comprising a plurality of solid oxide fuel cells, the solid oxide fuel cells further comprising a cathode inlet for receiving a compressed air, an anode inlet for receiving a fuel feed stream, an anode outlet in fluid communication with an anode exhaust stream and a cathode outlet in fluid communication with a cathode exhaust stream; wherein at least a portion of the fuel feed

stream reacts with the oxidant to produce electrical power and the anode exhaust stream comprises hydrogen; and

a separation unit in fluid communication with the solid oxide fuel cell assembly, wherein the separation unit is configured to receive the anode exhaust stream from the solid oxide fuel cell assembly to separate the hydrogen from the anode exhaust stream;

wherein the fuel cell is operated at a low utilization mode in which the output voltage is maintained substantially below 1.0 volt.

36. A method for co-production of hydrogen and electrical energy comprising:

introducing a fuel feed stream into a fuel cell assembly comprising a plurality of fuel cells;

operating the fuel cell assembly in a low utilization mode to produce electrical energy and producing an anode exhaust stream comprising hydrogen;

introducing the anode exhaust stream into a hydrogen separation unit; and

recovering a substantially pure hydrogen stream from the hydrogen separation unit.

37. The method according to claim 36 further comprising recycling at least a portion of the anode exhaust stream into the anode inlet after the separation of hydrogen.

38. The method according to claim 36, wherein the fuel cell is selected from the group consisting of solid oxide fuel cells, molten carbonate fuel cells, regenerative fuel cells, and protonic ceramic fuel cells.

39. The method according to claim 38 wherein the fuel cell is a solid oxide fuel cell.

40. A method for producing hydrogen from an anode exhaust stream from a solid oxide fuel cell assembly comprising a plurality of solid oxide fuel cells, the method comprising:

introducing the anode exhaust stream from the solid oxide fuel cell assembly to a carbon dioxide separator;

recovering two streams, a carbon dioxide rich stream and a carbon dioxide lean stream from the carbon dioxide separator;

introducing the carbon dioxide lean stream to a low temperature shift reactor and recovering a hydrogen rich stream; and

introducing the hydrogen rich stream to a hydrogen separator and recovering a substantially pure hydrogen stream from the hydrogen separator;

wherein the anode exhaust stream from the solid oxide fuel cell assembly comprises hydrogen, carbon dioxide, carbon monoxide and water.

41. The method according to claim 40 further comprising separating water from the anode exhaust stream.